IRPA

Airp

Associazione Italiana
di Radioprotezione

Old problems, new problems and opportunities
in medical field radiation protection

ENEA

ITALIAN NATIONAL AGENCY
FOR NEW TECHNOLOGIES,
ENERGY AND SUSTAINABLE
ECONOMIC DEVELOPMENT

EURADOS
European Radiation Dosimetry Group e. V.

Paolo Ferrari

Challenges of Radiological Protection
in Research and Society referring to Medical Field

October 3rd/2024 Milan, Italy

Caveat

The present work is an overview on some few aspects of the dosimetry and radiation protection in medical fields, mostly derived from my activity as coordinator of Working Group 12 of EURADOS (European Radiation Dosimetry Group) **https://eurados.sckcen.be/en**

EURADOS e. V. is registered in the German Register of Societies as a non-profit association for promoting research and development and European cooperation in the field of the dosimetry of ionizing radiation. 86 European institutions (Voting Members) and 650 scientists (Associate Members)

WG2 – Harmonization of individual monitoring
WG3 – Environmental dosimetry
WG6 – Computational dosimetry
WG7 – Internal dosimetry
WG9 – Radiation dosimetry in radiotherapy
WG10 – Retrospective dosimetry
WG11 – High energy radiation fields
WG12 – Dosimetry in medical imaging
Pilot Group - Dosimetry in Nuclear Medicine

Summary of the presentation

- **Dosimetry in pregnancy**
- **Dual energy CT dosimetry**
- **Patient (and staff) dose in interventional procedures**
- **Total (personalized) dose in Radiotherapy**

Dose in Pregnancy

In Diagnostic Radiology, if the fetus is in the beam, the procedure often can, and should be, tailored to reduce the fetal dose.

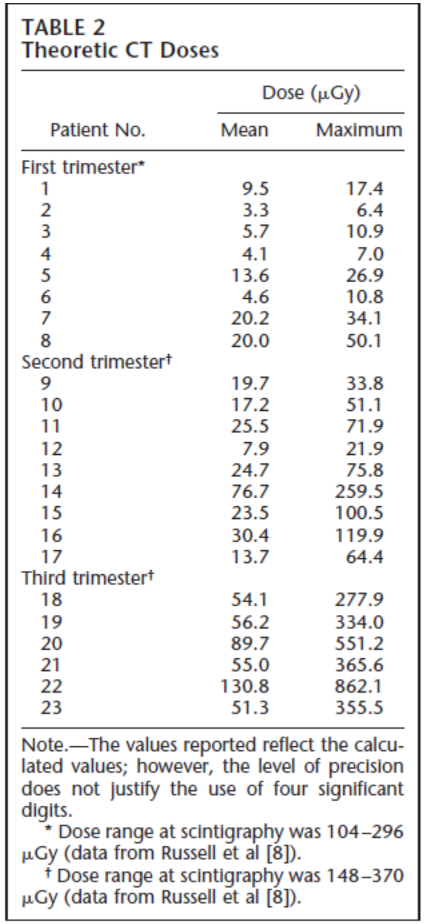


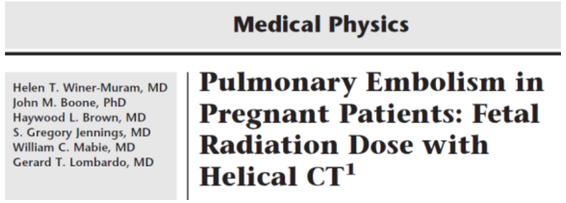
TABLE 2
Theoretic CT Doses

Patient No.	Dose (µGy)	
	Mean	Maximum
First trimester*		
1	9.5	17.4
2	3.3	6.4
3	5.7	10.9
4	4.1	7.0
5	13.6	26.9
6	4.6	10.8
7	20.2	34.1
8	20.0	50.1
Second trimester†		
9	19.7	33.8
10	17.2	51.1
11	25.5	71.9
12	7.9	21.9
13	24.7	75.8
14	76.7	259.5
15	23.5	100.5
16	30.4	119.9
17	13.7	64.4
Third trimester†		
18	54.1	277.9
19	56.2	334.0
20	89.7	551.2
21	55.0	365.6
22	130.8	862.1
23	51.3	355.5

Note.—The values reported reflect the calculated values; however, the level of precision does not justify the use of four significant digits.

* Dose range at scintigraphy was 104–296 µGy (data from Russell et al [8]).

† Dose range at scintigraphy was 148–370 µGy (data from Russell et al [8]).



Medical Physics

Helen T. Winer-Muram, MD
John M. Boone, PhD
Haywood L. Brown, MD
S. Gregory Jennings, MD
William C. Mabie, MD
Gerard T. Lombardo, MD

Pulmonary Embolism in Pregnant Patients: Fetal Radiation Dose with Helical CT[1]

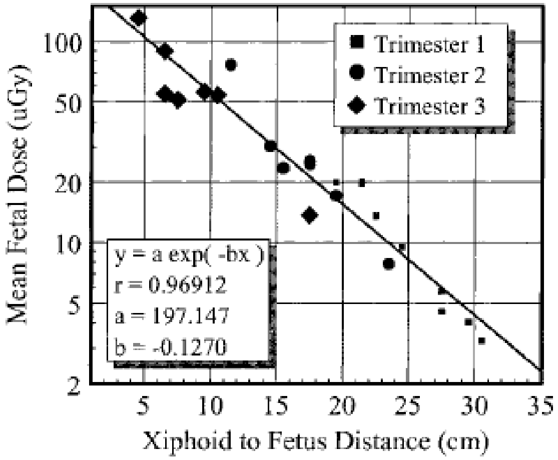
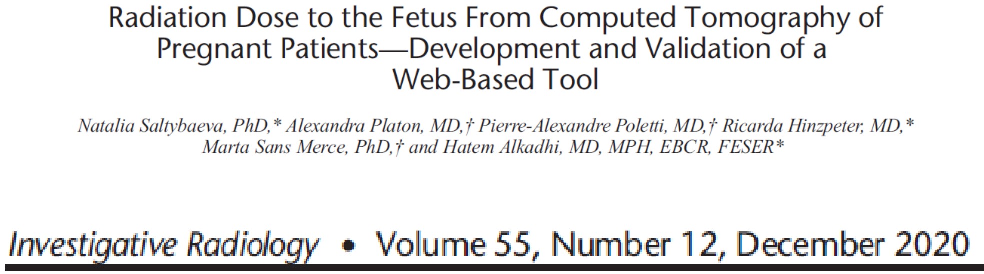


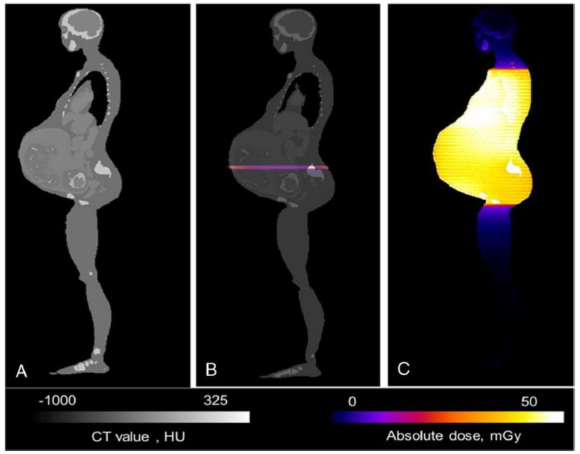
Figure 4. Graph shows the mean fetal dose for each of 23 patients. These data were determined by summing the dose contribution from each of the 44 CT sections in the study.



Radiation Dose to the Fetus From Computed Tomography of Pregnant Patients—Development and Validation of a Web-Based Tool

Natalia Saltybaeva, PhD, Alexandra Platon, MD,† Pierre-Alexandre Poletti, MD,† Ricarda Hinzpeter, MD,* Marta Sans Merce, PhD,† and Hatem Alkadhi, MD, MPH, EBCR, FESER**

Investigative Radiology • Volume 55, Number 12, December 2020



Aims of the task: To review, validate and compare different approaches for dosimetry in pregnancy for all imaging modalities (diagnostic and interventional radiology and nuclear medicine)

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Physica Medica 115 (2023) 103159

Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Original paper

Management of pregnant or potentially pregnant patients undergoing diagnostic and interventional radiology procedures: Investigation of clinical routine practice

Dario Faj[a,b], Céline Bassinet[c], Hrvoje Brkić[a,b,*], Francesca De Monte[d], Serge Dreuil[c], Laura Dupont[e], Paolo Ferrari[f], Aoife Gallagher[g], Lara Gallo[d], Christelle Huet[c], Željka Knežević[h], Ivana Kralik[i], Dragana Krstić[j], Carlo Maccia[k], Marija Majer[h], Francoise Malchair[l], Una O'Connor[m], Piotr Pankowski[n], Marta Sans Merce[e], Julie Sage[c],

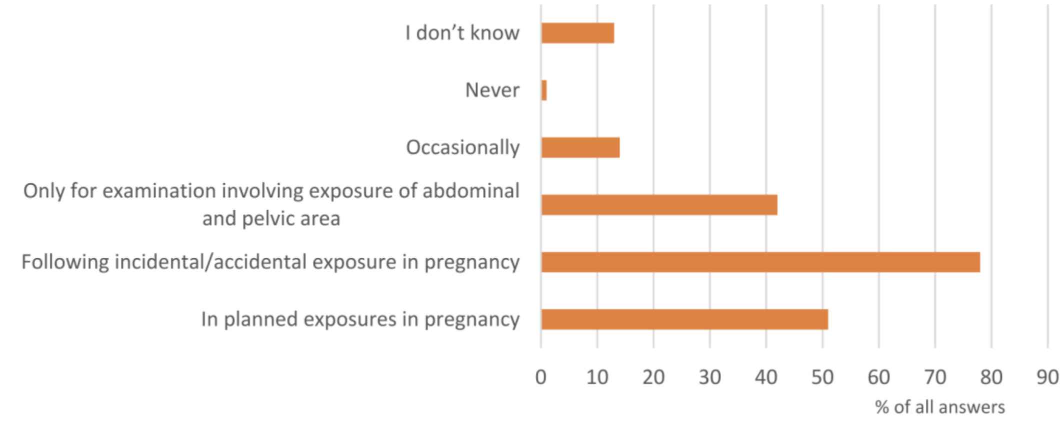

Fig. 2. Distribution of answers to the multiple-choice question "When is a dose assessment for the embryo/foetus related to the X-ray of the female pregnant patient performed?".

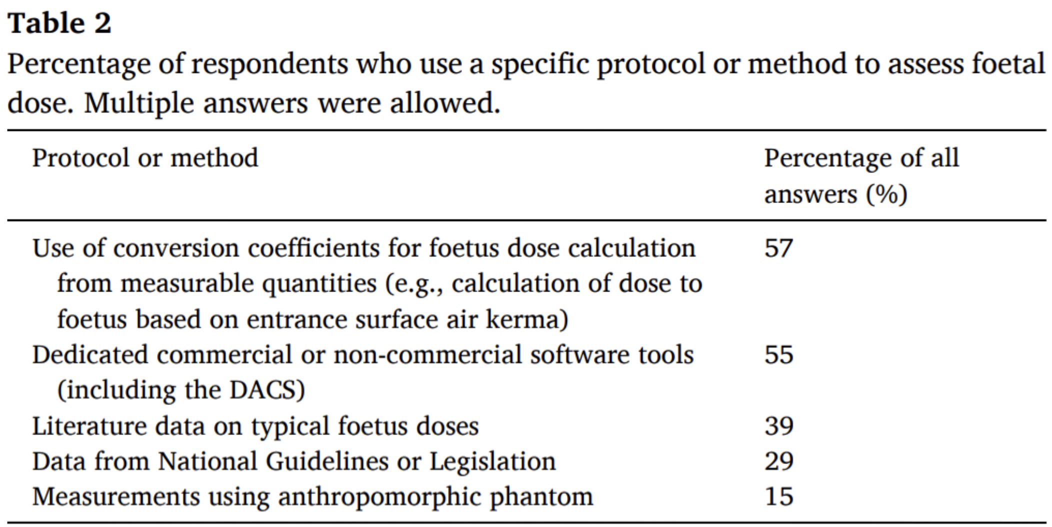

Table 2

Percentage of respondents who use a specific protocol or method to assess foetal dose. Multiple answers were allowed.

Protocol or method	Percentage of all answers (%)
Use of conversion coefficients for foetus dose calculation from measurable quantities (e.g., calculation of dose to foetus based on entrance surface air kerma)	57
Dedicated commercial or non-commercial software tools (including the DACS)	55
Literature data on typical foetus doses	39
Data from National Guidelines or Legislation	29
Measurements using anthropomorphic phantom	15

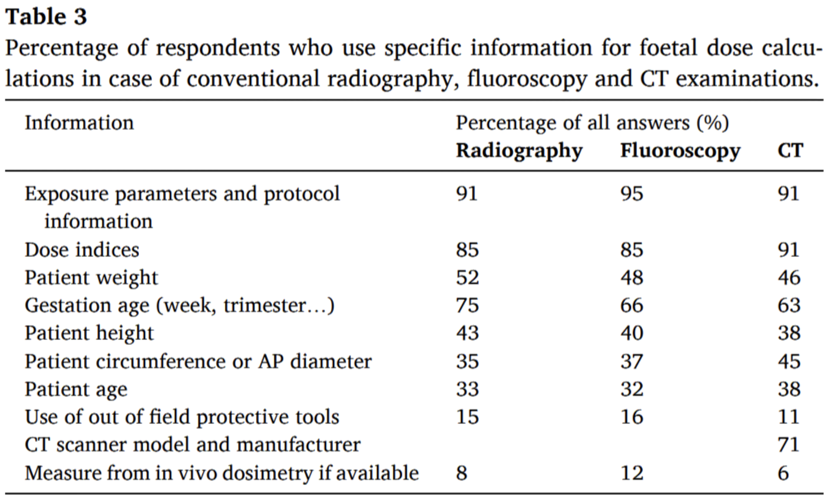

Table 3

Percentage of respondents who use specific information for foetal dose calculations in case of conventional radiography, fluoroscopy and CT examinations.

Information	Percentage of all answers (%) **Radiography**	**Fluoroscopy**	**CT**
Exposure parameters and protocol information	91	95	91
Dose indices	85	85	91
Patient weight	52	48	46
Gestation age (week, trimester…)	75	66	63
Patient height	43	40	38
Patient circumference or AP diameter	35	37	45
Patient age	33	32	38
Use of out of field protective tools	15	16	11
CT scanner model and manufacturer			71
Measure from in vivo dosimetry if available	8	12	6

Further steps of the task group study:

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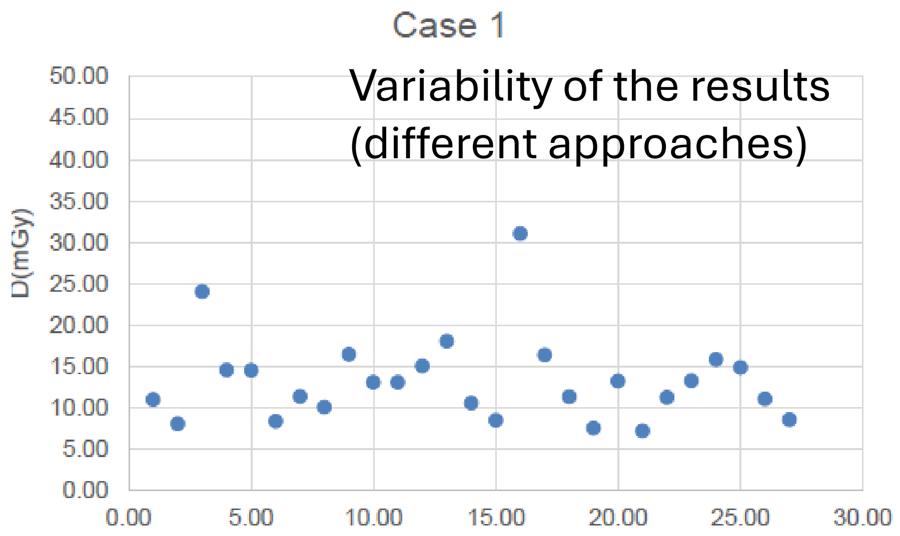
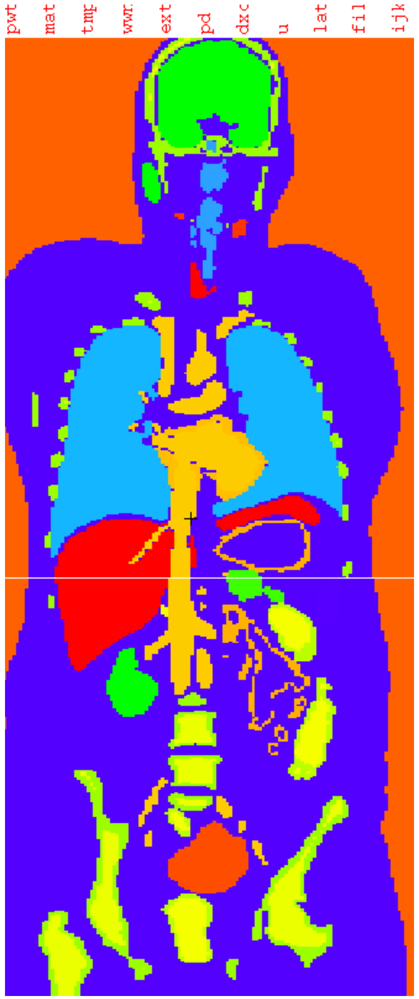
1. Determine the accuracy comparing different methodologies applied on 3 test cases
2. Perform measurements in clinical environment with a proper plastic phantom
3. Perform Monte Carlo simulations (validated through measurements) to determine the dose distribution.



Variability of the results (different approaches)


Plastic model



voxelized model

Dual Energy CT dosimetry

Dual-energy CT (DECT) can enhance the contrast resolution of CT images using different X-Ray spectra acquiring multiple energy data of a given anatomic area simultaneously and at the same time interval during the gantry rotation.

Radiologia 64 (2022) 445–455

RADIOLOGÍA

www.elsevier.es/rx

UPDATE IN RADIOLOGY

Dual-energy CT: Technical considerations and clinical applications

G.C. Fernández-Pérez[a,*], C. Fraga Piñeiro[b], M. Oñate Miranda[c], M. Díez Blanco[c], J. Mato Chaín[c], M.A. Collazos Martínez[c]

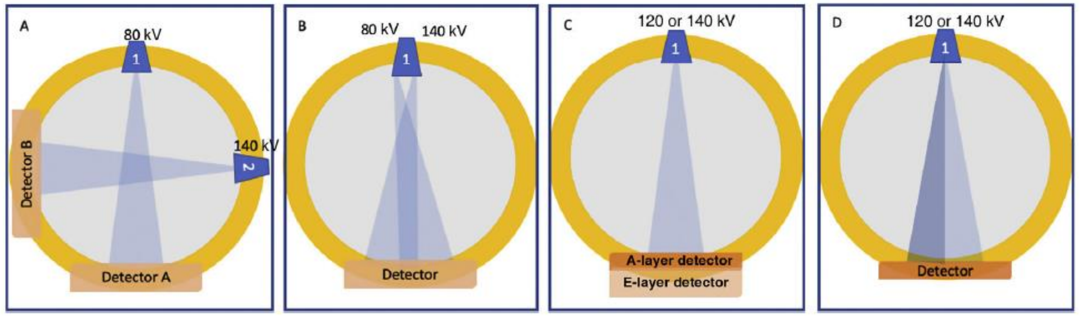
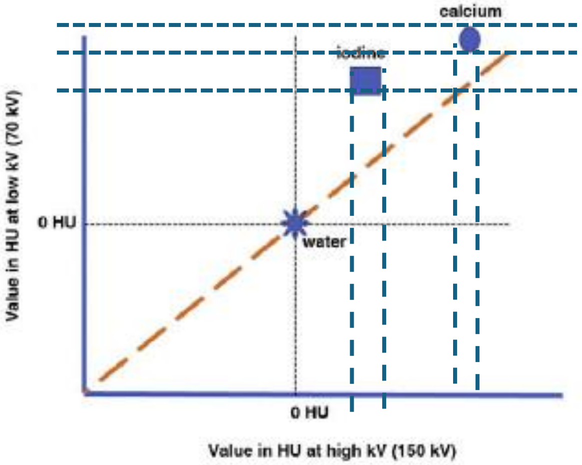


Figure 1 A) Dual source unit where one of the tubes emits high energy (140 kV) and a second low energy (80 kV), one perpendicul
to the other. The high-energy tube has a tin (Sn) filter, which absorbs low-energy photons to lower noise and increase spectr
differentiation efficiency. B) System where a single tube rotates rapidly, emitting exposures alternately to high (140 kV) and lo
energy (80 kV). C) System with a single tube that emits high energy (either 140 or 120 kV). Spectral separation occurs in the detect
where an A layer of yttrium is positioned which separates low energy photons, allowing high energy photons to interact on a secon
B layer of gadolinium oxysulfide. D) Filter system in the X-ray tube which causes the beam to be divided into two low and hig
energy emissions (split-filter).

$$\mu = \frac{\mu}{\rho}(E, Z)\,\rho$$



AAPM Report No. 204

Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations

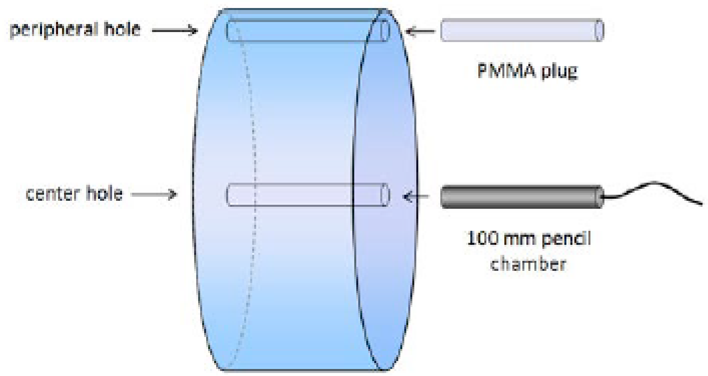


Figure 1. The general methodology for the assessment of CTDI$_{100}$ is illustrated. The 100 mm long pencil chamber is placed either at the center or at the periphery of a polymethyl methacrylate dose phantom. There are two standard PMMA phantoms, 16 cm and 32 cm in diameter and both are 15 cm in length. Unused holes are plugged with PMMA rods. The CTDI$_{100}$ methods are used to compute CTDI$_{vol}$, as described in the text.

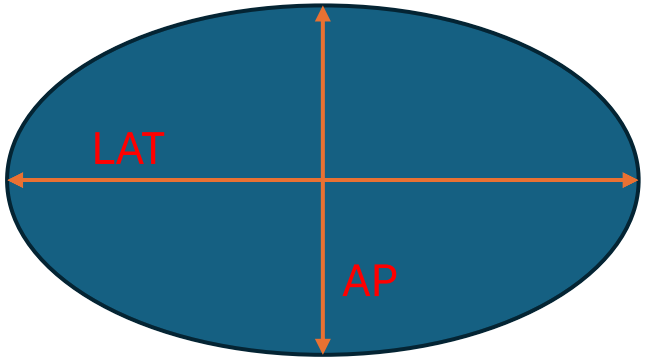
$$CTDI_{100} = \frac{1}{nT} \int_{z=-50mm}^{+50mm} D(z) \quad dz\,.$$

$$CTDI_{w} = \frac{1}{3} CTDI_{100}^{center} + \frac{2}{3} CTDI_{100}^{periphery}\,.$$

$$CTDI_{vol} = \frac{CTDI_{w}}{pitch}\,,$$

n number of slice, T slice thickness

Pitch = ratio of table feed per 360° rotation and collimated beam width (nT)



$$effective\ diameter = \sqrt{AP \times LAT}\,.$$

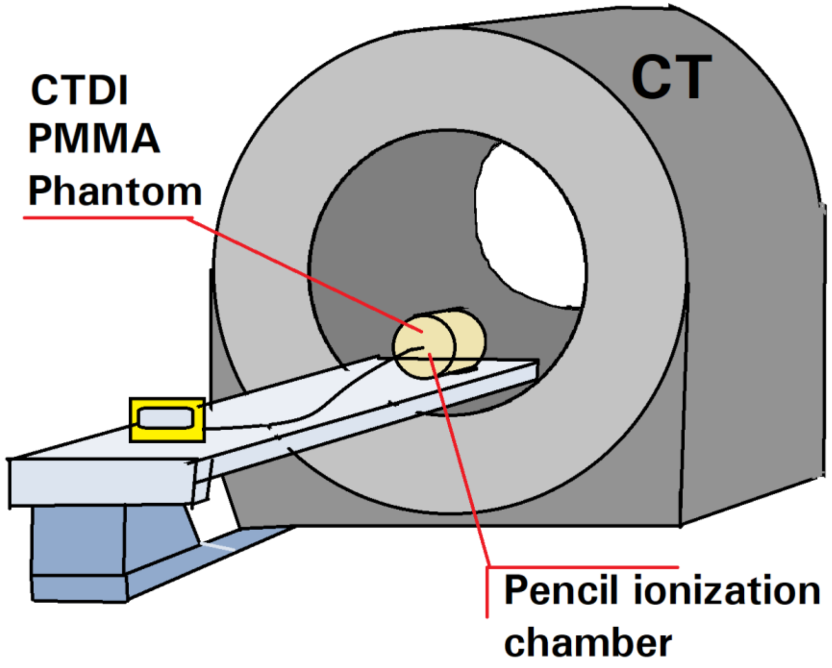
$$size\ specific\ dose\ estimate = SSDE = f_{size}^{32X} \times CTDI_{vol}^{32}\,,$$

Some studies show that the possibility of performing a virtual non-contrast imaging permits avoiding a whole phase of imaging (as with renal or angiographic imaging) that could reduce the dose (of particular interest in patients who require frequent follow-up CT examinations, e.g., every 6 months). If protocols are not adapted to remove the non-contrast phase, optimal dose savings will not be realized.

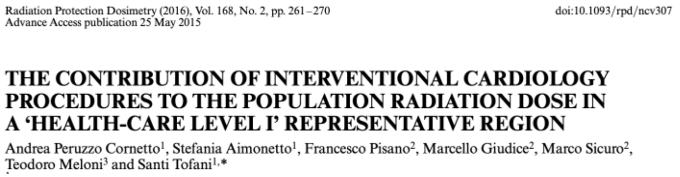
A possible efficient way to reduce radiation dose in CT (third generation DECT) is by adapting the scan parameters to the patient’s anatomy.

And how about CTDI (routinely Q.A. test performed to check the dosimetric characteristics of the installed equipment)? Is the CTDI procedure harmonized among manufacturers?

<u>Aims of the task</u> : Review current status of dosimetry for dual energy CT imaging and identify the shortcomings



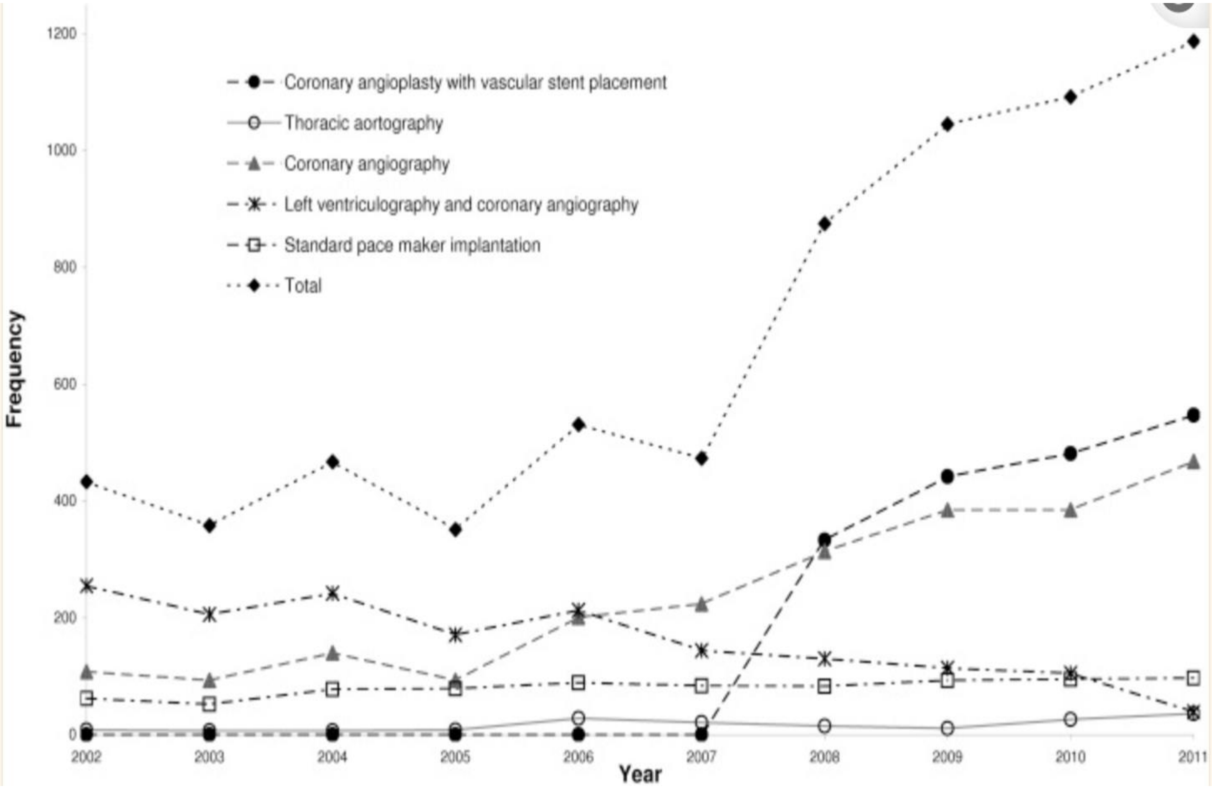
Interventional **P**rocedures



Radiation Protection Dosimetry (2016), Vol. 168, No. 2, pp. 261–270 doi:10.1093/rpd/ncv307
Advance Access publication 25 May 2015

THE CONTRIBUTION OF INTERVENTIONAL CARDIOLOGY PROCEDURES TO THE POPULATION RADIATION DOSE IN A 'HEALTH-CARE LEVEL I' REPRESENTATIVE REGION

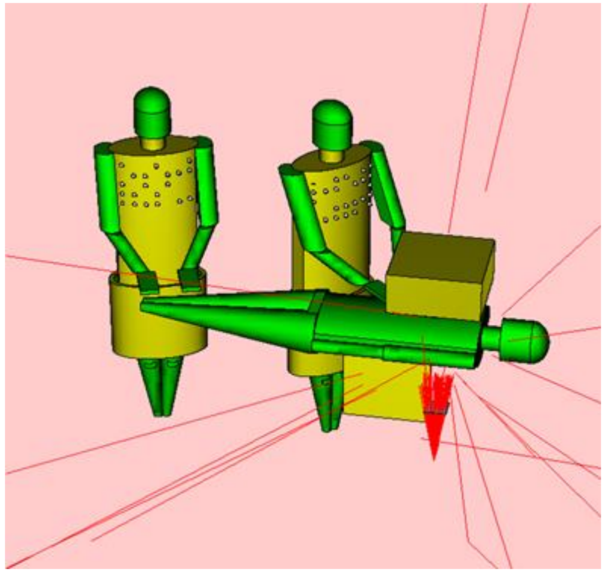
Andrea Peruzzo Cornetto[1], Stefania Aimonetto[1], Francesco Pisano[2], Marcello Giudice[2], Marco Sicuro[2], Teodoro Meloni[3] and Santi Tofani[1,*]



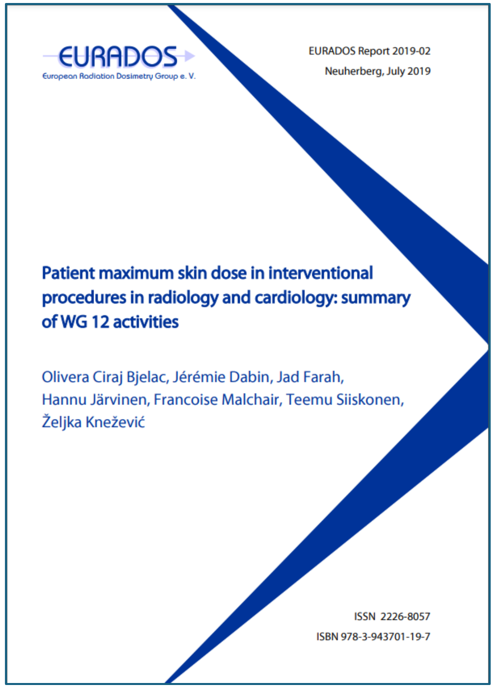
Total practices are almost tripled in cardiology in 10 years

Image from the web

Image from the web



Several types of dosimeters used to estimate patient's skin dose distribution.



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EURADOS Report 2019-02
Neuherberg, July 2019

Patient maximum skin dose in interventional procedures in radiology and cardiology: summary of WG 12 activities

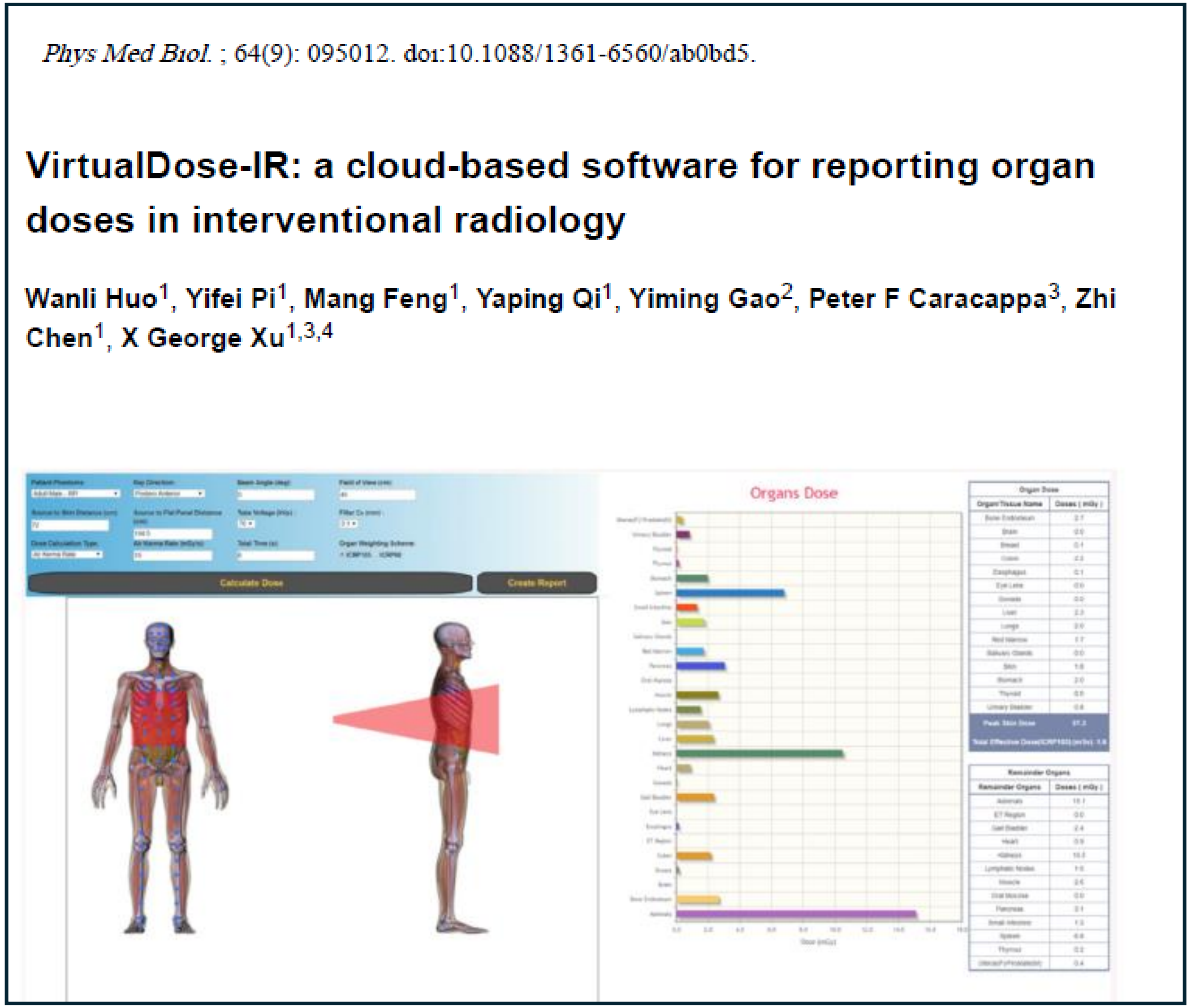
Olivera Ciraj Bjelac, Jérémie Dabin, Jad Farah,
Hannu Järvinen, Francoise Malchair, Teemu Siiskonen,
Željka Knežević

ISSN 2226-8057
ISBN 978-3-943701-19-7

Luminescence detectors GOOD energy and dose response BUT point-like estimation (risk to underestimate of the maximum skin dose).

Gafchromic® films probably the most convenient and affordable solution for clinical routine [uncertainty around 20 % (k=1)].

Skin dose alert levels could be set internationally as a function of an online dose indicator to prevent skin injuries and to identify which patients require follow-up.
GafChromic® films and TLDs is provides reasonably accurate determination of the skin dose alert levels but the measurements are time consuming.
In the future, software-based dose mapping tools may provide a more user-friendly approach



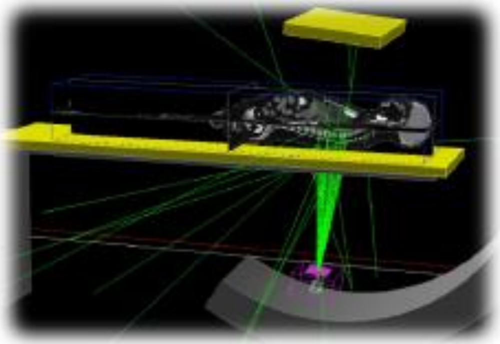
Phys Med Biol. ; 64(9): 095012. doi:10.1088/1361-6560/ab0bd5.

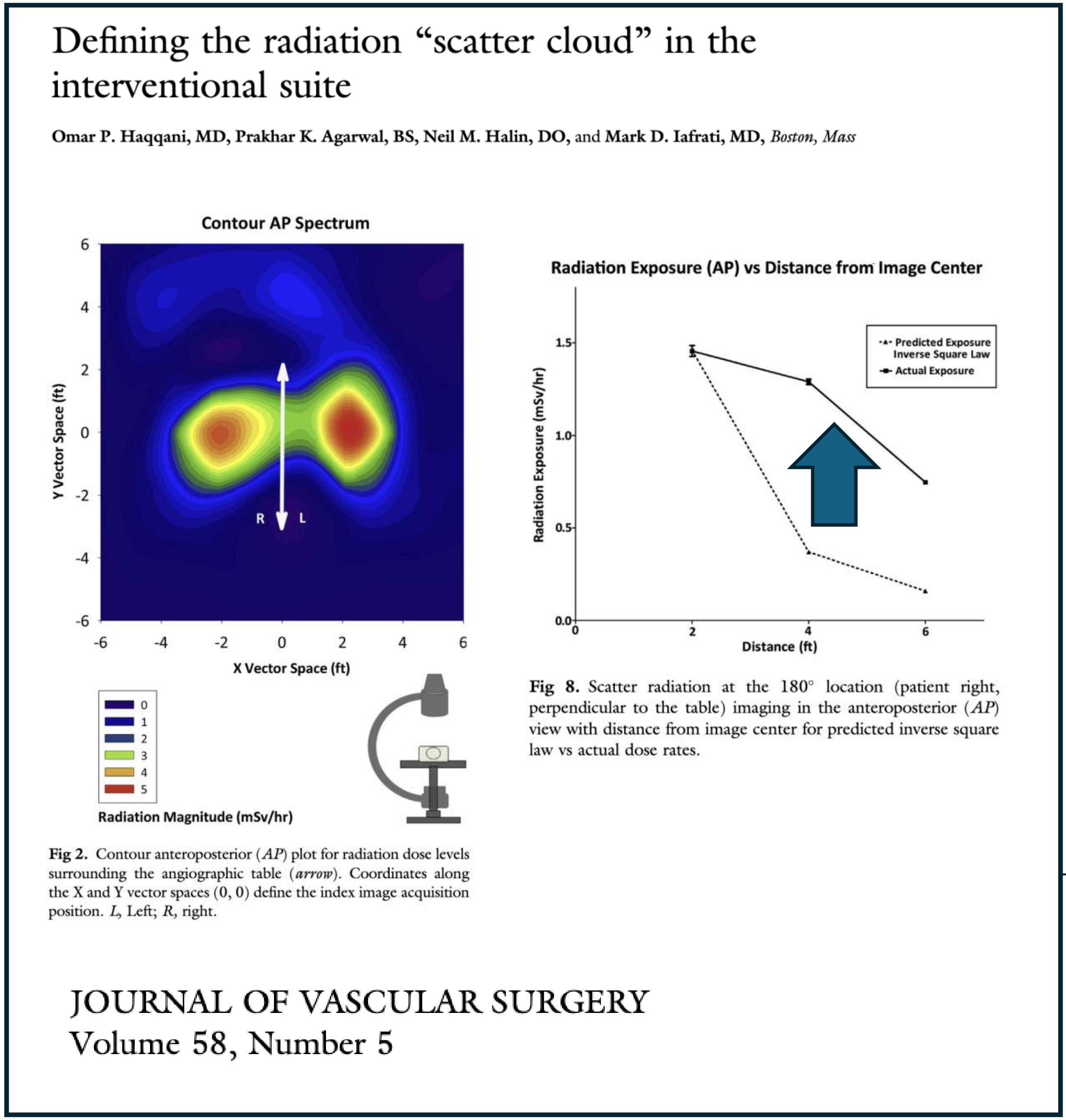
VirtualDose-IR: a cloud-based software for reporting organ doses in interventional radiology

Wanli Huo[1], Yifei Pi[1], Mang Feng[1], Yaping Qi[1], Yiming Gao[2], Peter F Caracappa[3], Zhi Chen[1], X George Xu[1,3,4]

Aims of the WG-12 task group:

1. Better understand the variability of the organ dose (measurements and simulations with MCNP, GATE/Geant4, Py-MCGPU, PHITS and SESAME)
2. To quantify organ dose changes as a function of beam/patient parameters
3. Compare with available commercial software





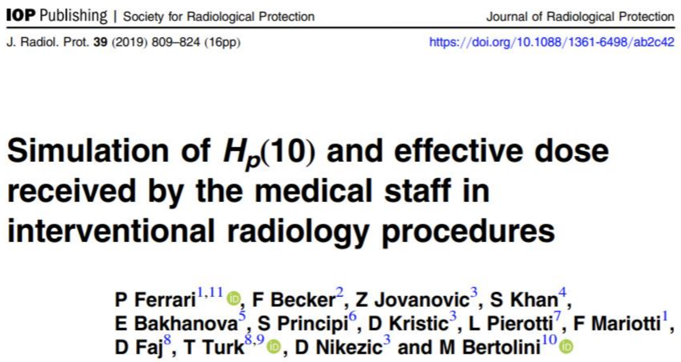
Defining the radiation "scatter cloud" in the interventional suite

Omar P. Haqqani, MD, Prakhar K. Agarwal, BS, Neil M. Halin, DO, and **Mark D. Iafrati, MD,** *Boston, Mass*

Fig 2. Contour anteroposterior (*AP*) plot for radiation dose levels surrounding the angiographic table (*arrow*). Coordinates along the X and Y vector spaces (0, 0) define the index image acquisition position. *L*, Left; *R*, right.

Fig 8. Scatter radiation at the 180° location (patient right, perpendicular to the table) imaging in the anteroposterior (*AP*) view with distance from image center for predicted inverse square law vs actual dose rates.

JOURNAL OF VASCULAR SURGERY
Volume 58, Number 5



IOP Publishing | Society for Radiological Protection Journal of Radiological Protection
J. Radiol. Prot. **39** (2019) 809–824 (16pp) https://doi.org/10.1088/1361-6498/ab2c42

European Radiation Dosimetry Group e. V.

Simulation of H_p(10) and effective dose received by the medical staff in interventional radiology procedures

P Ferrari[1,11], F Becker[2], Z Jovanovic[3], S Khan[4], E Bakhanova[5], S Principi[6], D Kristic[3], L Pierotti[7], F Mariotti[1], D Faj[8], T Turk[8,9], D Nikezic[3] and M Bertolini[10]

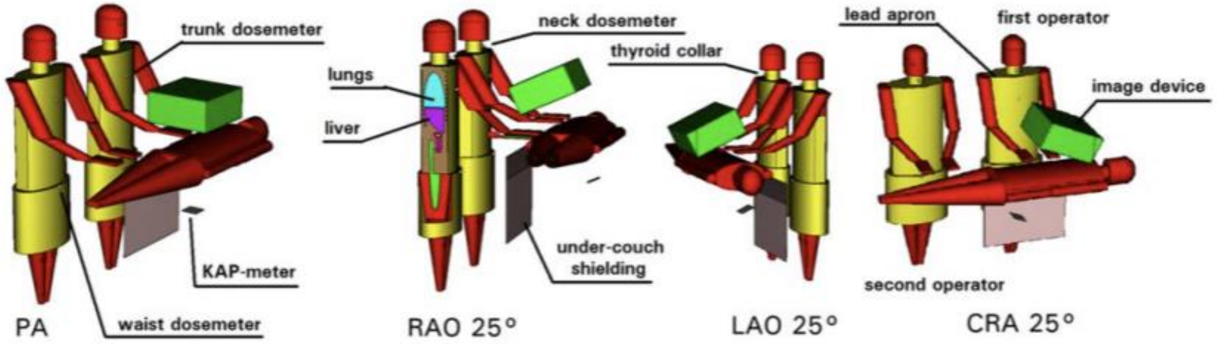


Figure 1. Geometries of the simulated scenarios for the four considered projections.

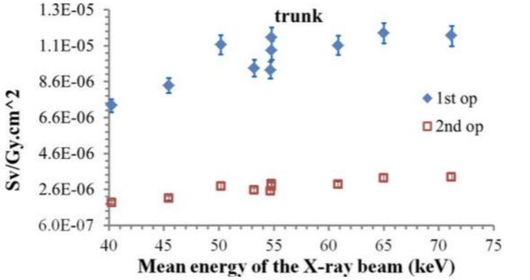


Figure 4. H_p(10) simulated at the breast level for the PA projection for the beam qualities of table 1.

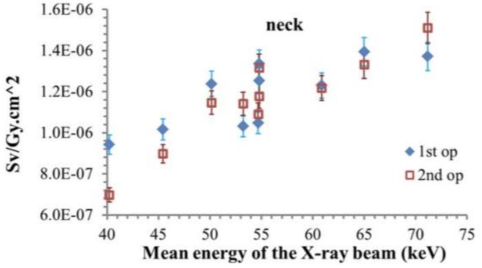


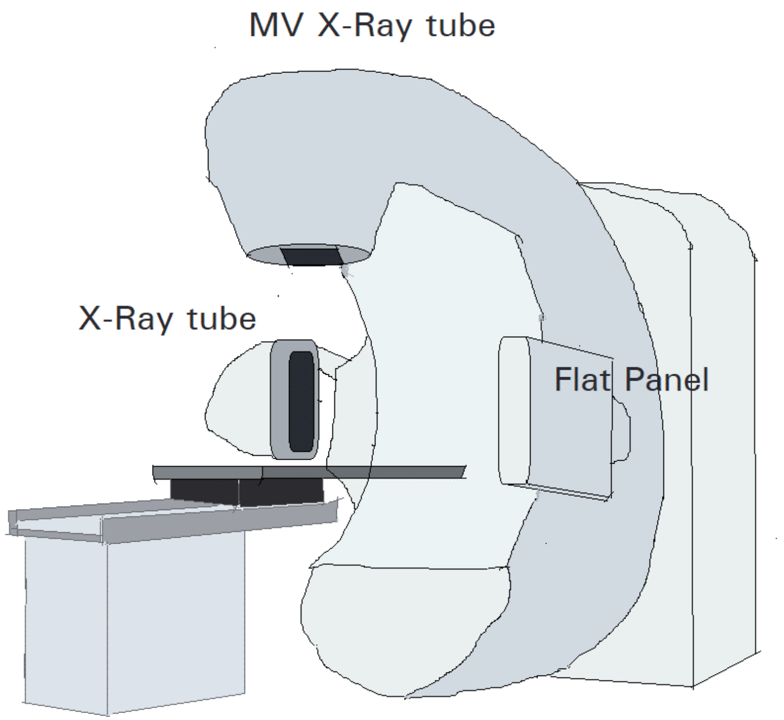
Figure 5. H_p(10) simulated at the neck level for the PA projection for the beam qualities of table 1.

Total (personalized) dose in Radiotherapy

IGRT (image guided radiation therapy) has become almost essential in modern radiotherapy due to the increased use of highly conformal treatment techniques using on-board kilovoltage cone beam computed tomography (CBCT).

IGRT image acquisitions are **frequent**, repeated on a daily basis, and include **a volume that is larger than the treated one**.

The dose derived from imaging to sensitive organs can potentially increase the chance of secondary cancers and, therefore, needs to be managed.



Medical Physics, 45 (5), May 2018

Image guidance doses delivered during radiotherapy: Quantification, management, and reduction: Report of the AAPM Therapy Physics Committee Task Group 180

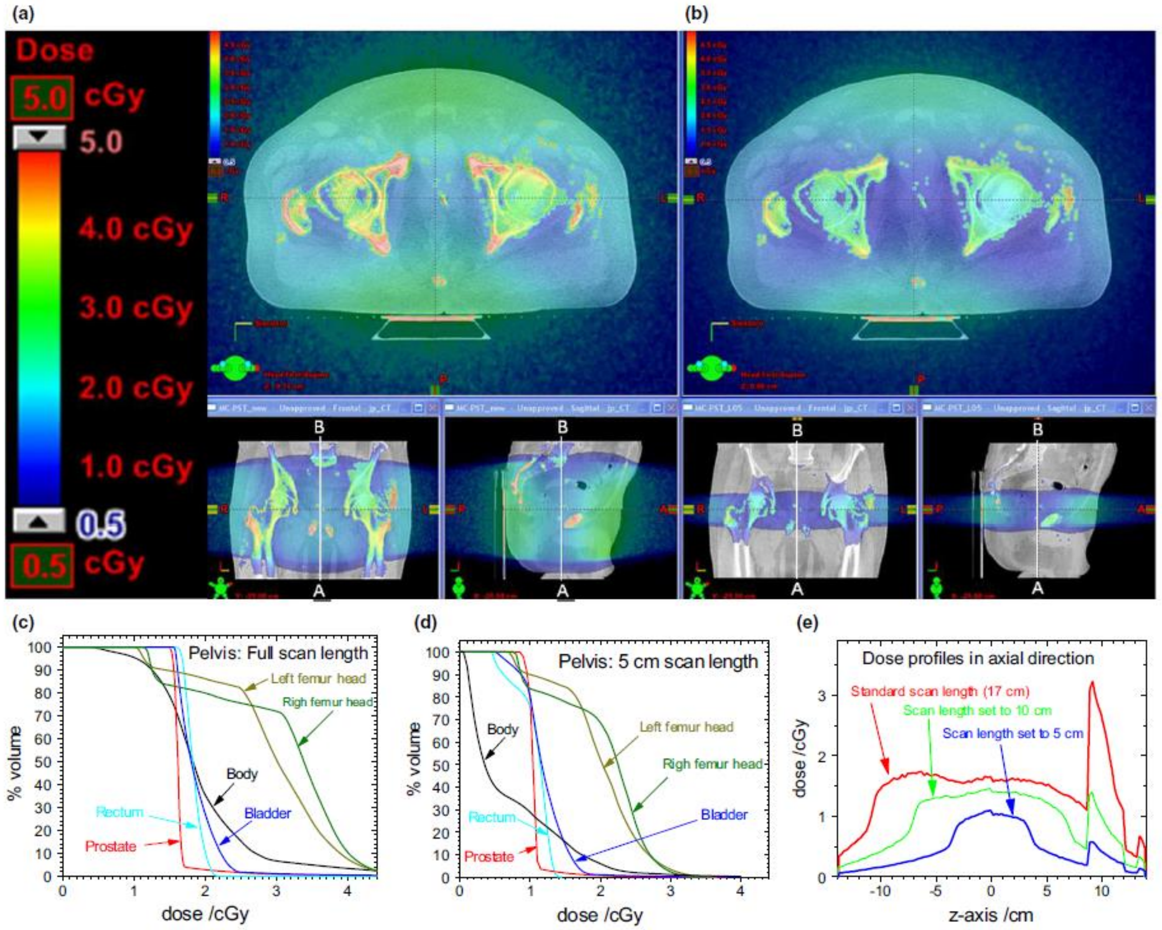


Fig. 5. The effect of reducing the scanned length: (a) Dose distributions shown in colorwash for default Pelvis scan length (16 cm); (b) reduced Pelvis scan length (5 cm); (c, d) Corresponding dose-volume histograms for the specific organs resulting from respective scans; (e) Dose profiles in the inferior–superior direction along the line AB shown in Figure (a,b) across the irradiated volume for 16 cm (standard scan length), 10 cm, and 5 cm, respectively. The direction of z-axis is from inferior to superior in (e). The peak at the right in (e) represents the dose as the line AB crosses into the sacral vertebral body (bone). Note that reducing the scan length of the CBCT scan reduces both the maximum dose and the volume that is exposed to radiation. Reproduced from Ding et al.[29] (Scanning parameters are listed Table IId).

a) Create local imaging protocols, including imaging modality, technique, and frequency, that are suitable for the imaging requirements of the clinic. Consulting with a diagnostic imaging physicist may be helpful in this process.
b) Develop protocols that are specific for pediatric patients.
c) Communicate the imaging dose associated with IGRT protocols by site (head, thorax, abdomen, pelvis) to radiation oncologists. This enables informed decision-making for selecting imaging protocols and ensures the clinicians are aware of the imaging doses being delivered to their patients.

Aims of the WG-12/WG-9 joint task :

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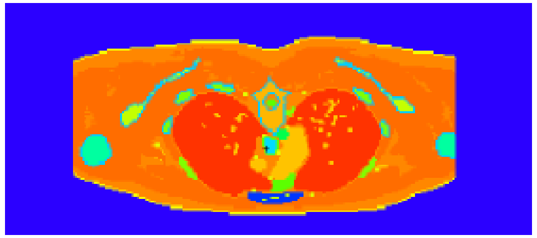
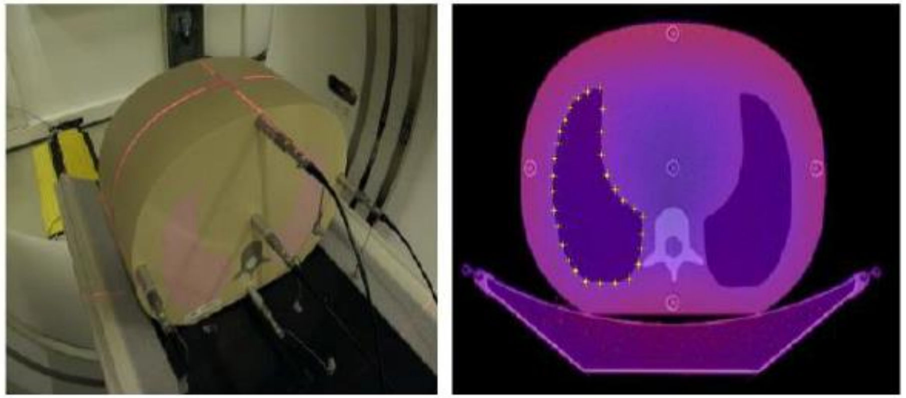
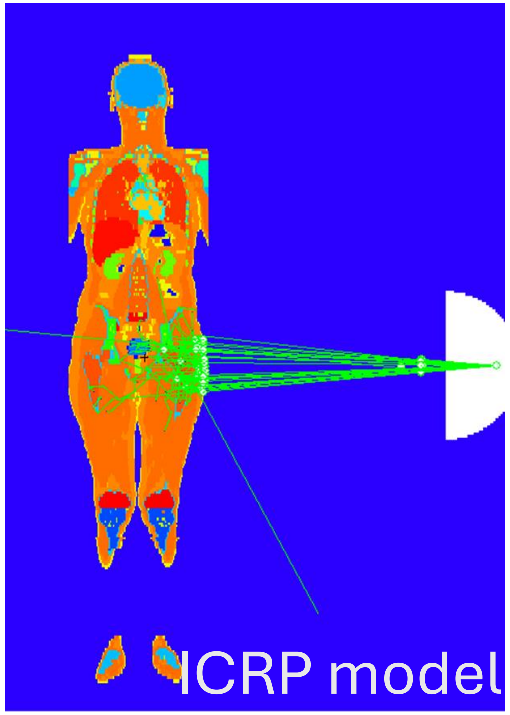
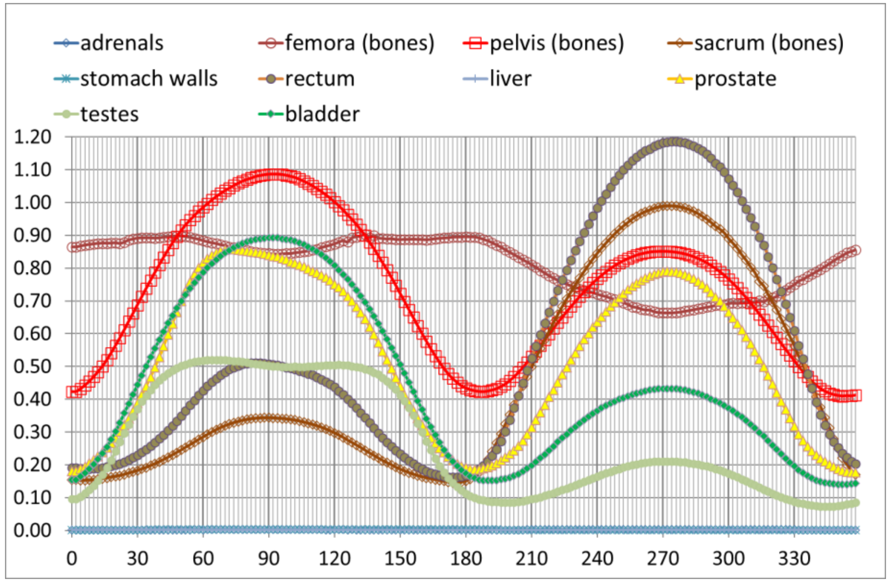
1. To establish reliable way to assess the total patient dose from the whole radiotherapy process to promote the optimization of patient exposure
2. To analyze the imaging practices in Europe and to provide guidance on:
   a. Imaging dose optimization
   b. Imaging practices for selected treatments



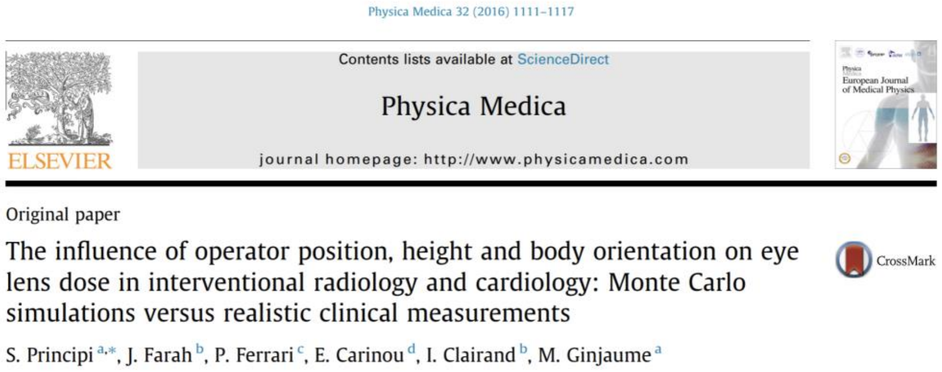






Simulated CBCT doses to pelvis organs

Thank you for your kind attention



Physica Medica 32 (2016) 1111–1117

Contents lists available at ScienceDirect

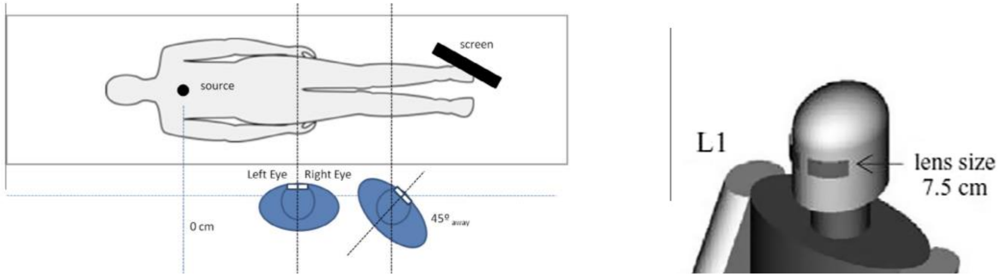
Physica Medica

journal homepage: http://www.physicamedica.com

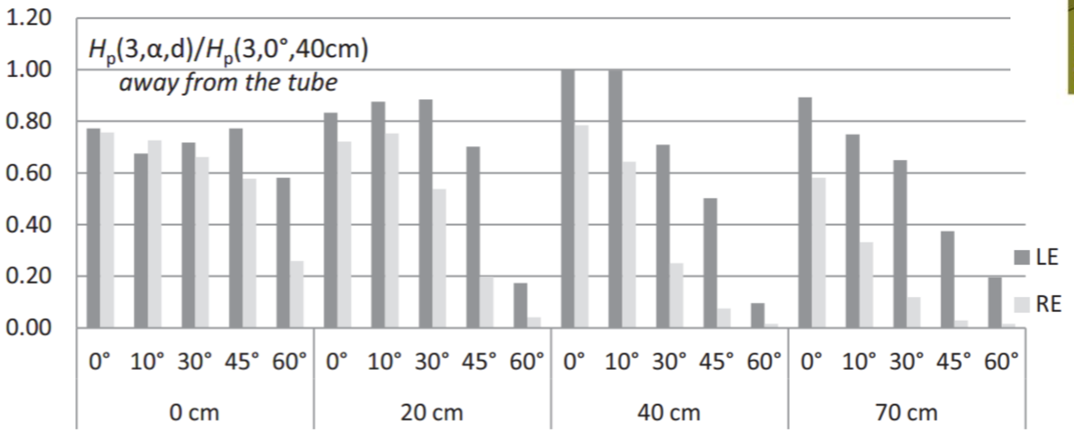
Original paper

The influence of operator position, height and body orientation on eye lens dose in interventional radiology and cardiology: Monte Carlo simulations versus realistic clinical measurements

S. Principi[a,*], J. Farah[b], P. Ferrari[c], E. Carinou[d], I. Clairand[b], M. Ginjaume[a]



(a) (b) (c)



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Original paper

Absorbed dose in the operator's brain in interventional radiology practices: evaluation through KAP value conversion factors

Paolo Ferrari[a,*], Zoran Jovanovic[b], Elena Bakhanova[c], Frank Becker[d], Dragana Krstic[b], Jan Jansen[e], Sara Principi[f], Pedro Teles[g,h], Isabelle Clairand[i], Željka Knezevic[j]

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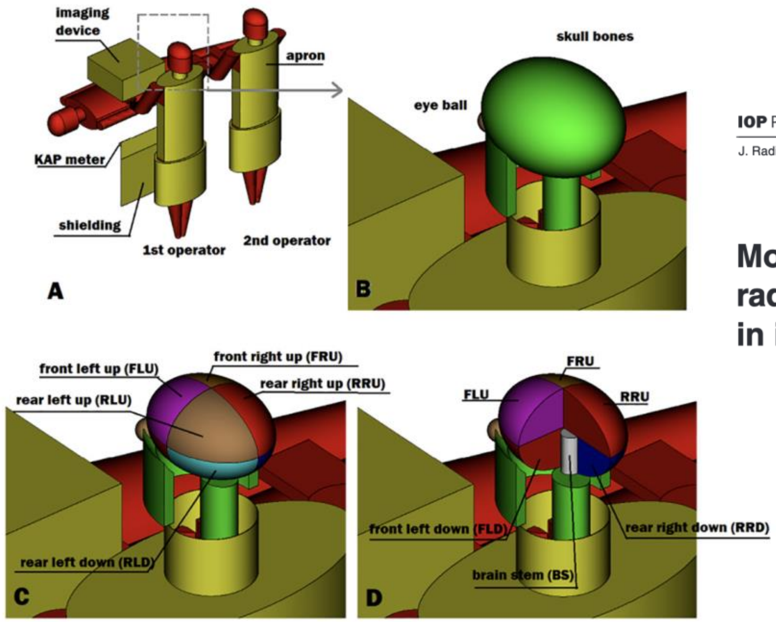

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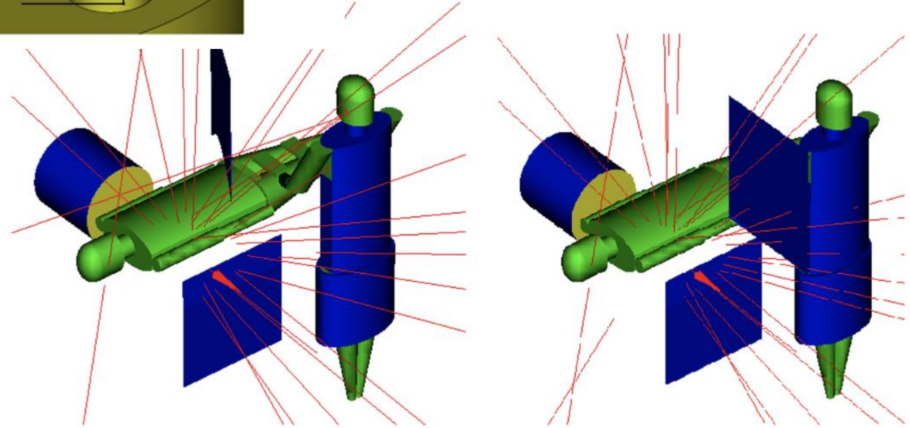
Monte Carlo study of the scattered radiation field near the eyes of the operator in interventional procedures

Paolo Ferrari[1], Frank Becker[2], Eleftheria Carinou[3], Vadim Chumak[4], Jad Farah[5], Zoran Jovanovic[6], Dragana Krstic[7], Artem Morgun[8], Sara Principi[9] and Pedro Teles[10]



J. Radiol. Prot. 42 (2022) 041501 https://doi.org/10.1088/1361-6498/ac9394

Journal of Radiological Protection

PAPER

Feasibility study of computational occupational dosimetry: evaluating a proof-of-concept in an endovascular and interventional cardiology setting

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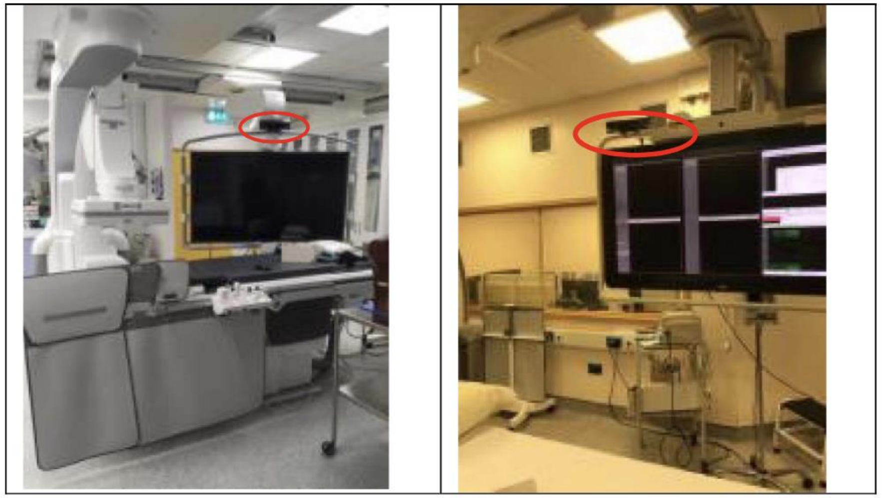

Figure 1. Location of camera installed in endovascular x-ray room (left) and cardiac cath lab (right).

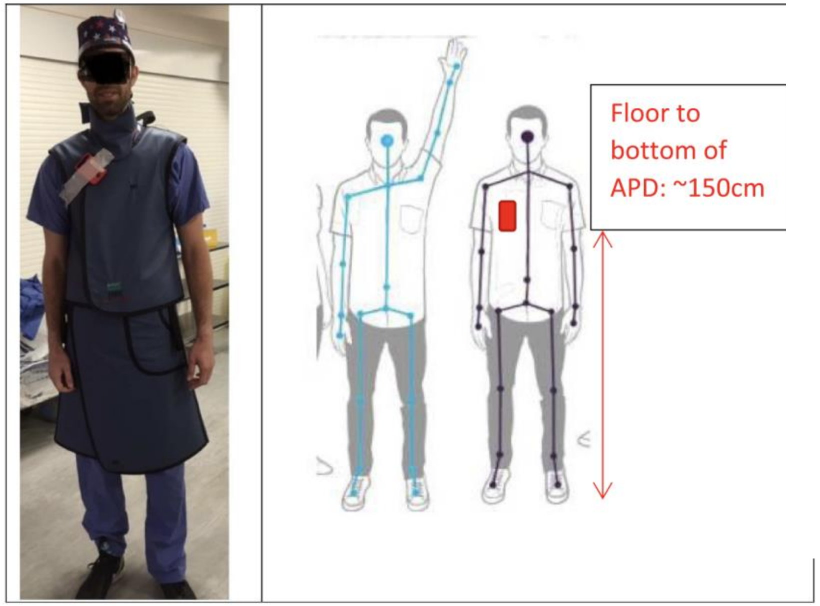

Figure 5. The APD worn by the main operator, and the approx. position of the APD used for simulations, taking into account the operators height.

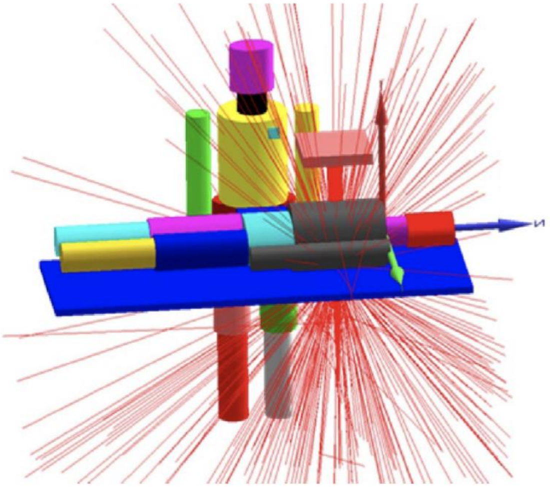

Figure 2. Simplified geometry used in MCNPX simulations.

Figure 7. Example of skeleton tracking overlapping (two operators but only one skeleton identified).